

# Water Jet Cutter: An Efficient Tool for Composite Product Development

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## ABSTRACT

*Water jet cutter is a powerful tool in the present engineering scenario which works on the principle of micro erosion occurring when large volume of water is forced through a nozzle of reduced cross section at high velocity (~Mach No: 3) and elevated pressure (~3000 bar). Water jet cutter was used to cut lumber by forestry engineer Dr. Norman Franz in 1950s.<sup>[1]</sup> Water jet cutting find applications in diverse industries from mining to aerospace, where it is used for cutting, shaping, carving and reaming. Water jet cutting has many advantages like no local heat generation, smaller kerf width hence less material wastage, faster and cheaper, higher accuracy, automation capability, and less burr and rough edge etc. Advanced Composites Division (ACD) is actively engaged in the development of various aircraft parts for on-going National Programmes like TEJAS, SARAS etc. For the development of composite parts the most important aspect is tooling. To develop a tool, one has to start with master model. The technology used in ACD for composite tooling is based on splash technique. To fabricate master models and moulds, we require templates such as base plates, master model check templates, mould-ribs, reference pad fixing location templates and mould check templates etc. These are cut precisely using water jet cutter.*

*In this paper, importance of the water jet cutter for composite tooling, space structure fabrication and ceramic test coupon generation has been highlighted. Abrasive water jet technique is normally used to cut hard materials like titanium, ceramics, Kevlar fibre composites etc., The advantage of using water jet cutter with abrasives is also addressed.*

**Keywords:** Water Jet Cutter, Abrasives, Lumber, Micro Erosion.

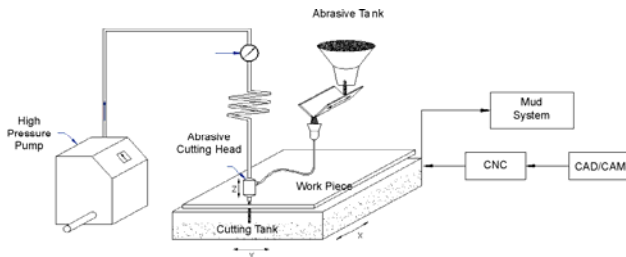
## 1. INTRODUCTION

It is well-known that the rivers and streams form paths cutting through mountain and valleys due to the fact that the continuously flowing water gradually erodes the surfaces it contacts. The slow erosion process can be transformed into high speed cutting action when the force of the water is increased using current technology. When water is compressed to an ultra high pressure level such as 3000 bar and released through the nozzle having small bore diameter of 0.2 to 0.3 mm, the expanding water attains an estimated speed up to three times the velocity of sound (Mach No. 3). The focused jet of water traveling at an estimated speed of

869 m/s releases sufficient kinetic energy to cut through most hard-to-cut materials. The cutting action of the high pressure water jet involves a compressive shearing action, resulting in loss of material in the path of water flow. The loss of material occurs in the cut path because of the constant erosion by the high kinetic energy of the coherent jet of water. Water jet cutting is a well known technology that is finding applications in the domain of engineering and technology.<sup>[2]</sup>

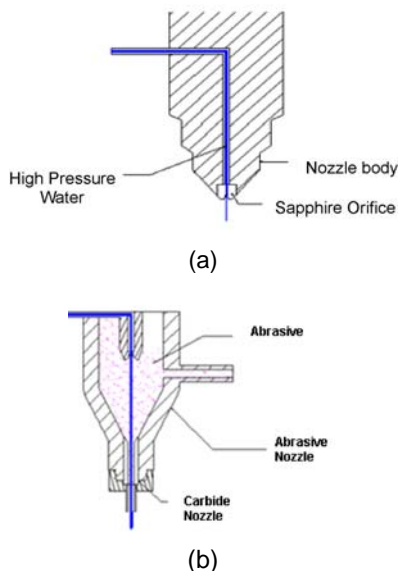
Many problems like poor edge quality, damage of product quality and integrity by the medium used encountered with other cutting methods like diamond cutting, Electrode Discharge Machining (EDM), wire

cutting etc can be alleviated in water jet cutting. The cutting performances in terms of speed and accuracy are also becoming more demanding and these can be achieved by using water jet cutting. The typical water jet cutting machine will have major sub systems like high pressure pump to increase the water pressure required to have sufficient kinetic energy, abrasive tank, abrasive cutting head, cutting tank, mud system, Computer Numerical Controlled (CNC) system and Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) etc. The general layout of water jet cutting machine is shown in Fig. 1.



**Fig. 1:** General Layout Showing Water Jet Cutting Machine<sup>[2]</sup>

The equipment associated with a water jet-cutting system performs three major functions including generation, distribution and control of high-pressure water for cutting. The cutting nozzle assembly systems used in both water and abrasive water jet cutting is shown in Fig. 2a and b.



**Fig. 2:** A Schematic Showing the Cutting Head Systems: (a) Water Jet Cutting and (b) Abrasive Water Jet Cutting

In this paper, the work carried out using both types of water jet cutting under the composite based aircraft components development and other materials development programs of NAL, Bangalore and other organizations is discussed.

## 2. EXPERIMENTAL DETAILS

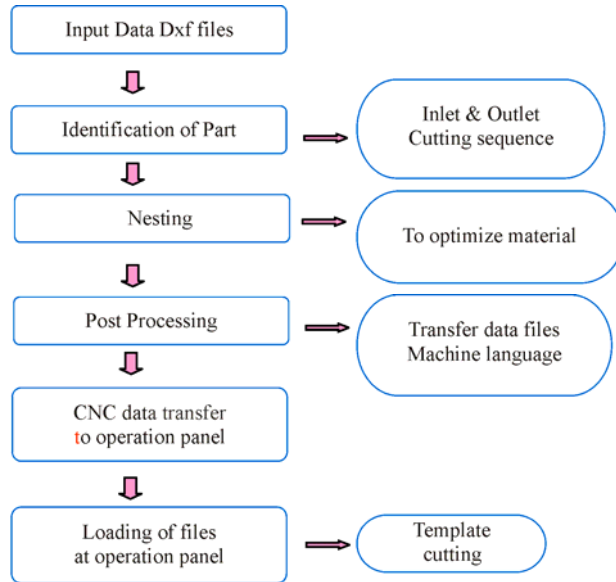
The development of composite based components for any intended applications (Example: Air craft components) involves namely CAD model preparation based on conceptual design followed by 2D manufacturing drawing after design acceptance, preparation of master models out of plaster of Paris, preparation of moulds out of Carbon Fiber Reinforced Plastic (CFRP), making of derivative tools and finally making of actual components. In all the stages of the composite component development, the water-jet cutting plays a key role in getting the followings:

1. Master model casting template, base plate with cutouts, location holes etc, spacers for casting, master model check templates for inspection of master model.
2. Mould preparation (tool), ribs for reinforcement, reference pad, reference pad fixing to locate templates and mould check templates.
3. Ribs alignment/location/positioning templates out of CFRP needed while lay up and curing part trimming template, part checking template etc.

Generally, to generate any item (example. checking templates, tools, moulds etc.) of interest, the CAD drawing in Data Exchange File (DXF) format is taken and programmed appropriately. The care is taken on loading the specimens during cutting etc, to achieve the higher level accuracy and minimize the rejection. The general steps involved in the water jet cutting are shown in Fig. 3.

Silicon carbon fibre reinforced/Silicon carbide ceramic matrix composites ( $\text{SiC}_f/\text{SiC}$ ) and other monolithic ceramics. Like silica, alumina etc., being developed at National Aerospace Laboratories (NAL) are cut using abrasive water jet cutting and samples for tensile strength (dog bone specimen), flexural strength (bar specimens), R-curve studies (Compact Tensile (CT) specimen), thermal conductivity studies (disc specimen) are generated to the required dimensions and accuracy with minimal material wastage. Templates needed for Jigs and fixtures are also generated abrasive water jet cutting

for the inspection. The water jet cutting system used for carrying out all the studies is shown in Fig. 4a (M/s. WARICUT cutting systems, Germany) and the close up view of abrasive water jet cutting assembly is shown in Fig. 4b.



**Fig. 3:** Flow Chart Shows the General Steps Involved in the Water Jet Cutting



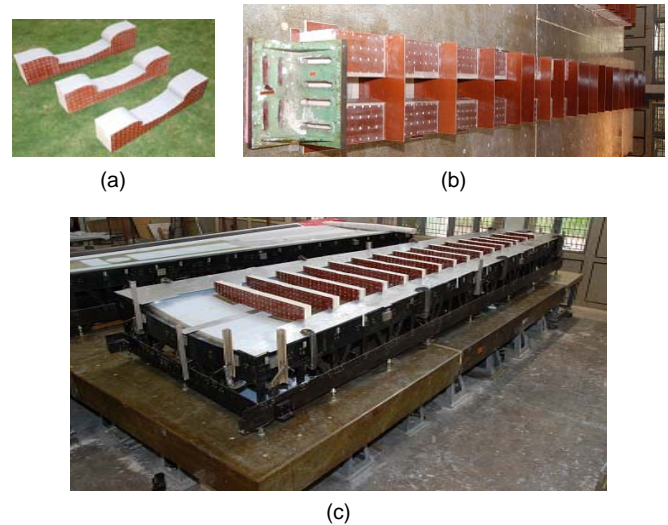
**Fig. 4:** Overall View of a) Cutting Machine  
b) Close Up View of Abrasive Water Jet Cutting

### 3. RESULTS AND DISCUSSIONS

Hylem and Carbon Fiber Reinforced Plastic (CFRP)/thin composite textile based master model templates are cut by water jet cutting. An appropriate job loading arrangement was successfully developed to cut master model templates to the higher accuracy and less rejection, large number of master model templates are cut and few of them are shown in Fig. 5a and b.

Ribs, reference pads and location of pads (shown Fig. 5c) required for casting moulds are cut using abrasive water jet cutting method. The typical cutting parameters arrived after many apparent trials are water pressure: 3200

bar, abrasive feed rate: 340 g/min, distance between nozzle tip and the job = 3 mm. The cutting performed using the above parameters yield the machined parts with good finishing and higher accuracy. The typical parts cut are shown in Fig. 6a and 6b.



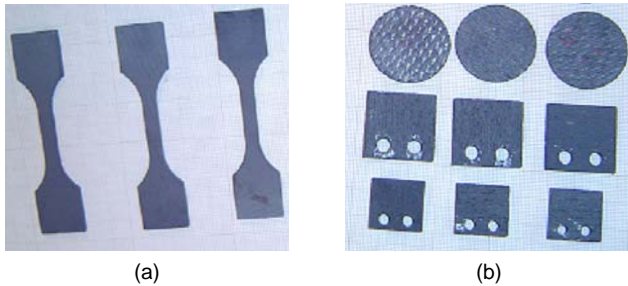
**Fig. 5:** Photographs Showing a) Master Model Segments and b) Master Model Checking Template Arrangement



**Fig. 6:** Photos Showing Gear Cut Through Abrasive Water Jet Cutting (a) Hylem and (b) Steel

The abrasive used in all cases is garnet ceramic powder (M/s MD Associates, Bangalore,  $100 \pm 10$  meshes). Nozzle used for both water and abrasive water jet cutting is synthetic sapphire or diamond having the diameter of 0.2 to 0.3 mm and the focusing tube with 1mm diameter. By maintaining water quality and practicing the good maintenance, the life of the expensive nozzle is improved. Originally, water jet cutting was used to cut  $\text{SiC}_f/\text{SiC}$  composites. The poor edge quality and de lamination in the parts were observed. After many trial experiments with the abrasive water jet,  $\text{SiC}_f/\text{SiC}$  composites were cut and samples for various Characterization (tensile, thermal diffusivity, flexural Strength, compact tensile test

specimens for R-curve studies) are generated with no de lamination. The typical specimens generated are shown in Fig. 7a and 7b.



**Fig. 7:** Photographs Showing a) Tensile Specimens Out of SiC/SiC Composites b) CT and Disc Specimens Out of SiC/SiC Composites

In particular for generating the smaller diameter specimens the circular profile was intentionally made incomplete (by 1 to 2 mm) in the CAD drawing itself to retain the cut sample within the job. If the circular profile is completed, most of the time the sample is lost in the cutting tank and getting the sample was very difficult.

#### 4. CONCLUSIONS

Master models, check templates, composite component and ceramics/ceramic matrix composites required for various on-going composite product development and R&D activities of NAL, Bangalore were successfully swaged. The dimensional accuracy and edge quality achieved were greatly accepted. The facility was also extensively used for other organizations such as Advanced Systems Laboratories (ASL) Hyderabad, Hindustan Aeronautics Limited (HAL) Bangalore,

Indian Space Research Organization (ISRO) satellite centre Bangalore, Aeronautical Development Agency (ADA) Bangalore and Centre for Airborne Systems (CABS) Bangalore for their component development and R&D activities. The cutting parameters arrived after many trials were used for all the cutting activities and higher accuracy/high cut edge quality was achieved. Suitable maintenance and a good house keeping procedures were developed and high quality cutting environment was achieved.

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